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A Mixed Logit Approach to Study Preferences for Safety on Alpine Roads

Christoph M. Rheinberger

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Abstract This paper presents a mixed logit approach to the valuation of reductions in mortality risk on Alpine roads. In addition to common road accidents, users of these roads face risks from natural hazards such as avalanches and rockfalls. Moreover, the individual risk of road users varies with the frequency of their exposure. Drawing on choice experimental data of frequently exposed respondents from a mountainous region and less frequently exposed respondents from a city in Switzerland, we are able to estimate the value of statistical life (VSL). Furthermore, we explore how respondents differ in their individual willingness-to-pay depending on exposure and other individual characteristics. Our estimates of the VSL in the context of fatal accidents on Alpine roads are in the range of CHF 6.0–7.8 million (€3.9–5.1 million). We find the VSL to be dependent on socio-economic and perceptional factors but to be not significantly altered by the type of hazard. These findings imply that the VSL might be adjusted to account for heterogonous risk preferences of different societal groups, but there is no evidence of a 'dread' premium for natural hazards.

Keywords Mortality risk · Value of statistical life · Natural and man-made hazards · Mixed logit model · Preference heterogeneity

JEL Classification D81 · J17 · R42

C. M. Rheinberger (✉)
LERNA, Toulouse School of Economics, Manufacture des Tabacs, 21 Allée de Brienne,
31000 Toulouse, France
e-mail: crheinbe@univ-tlse1.fr

C. M. Rheinberger
WSL Institute for Snow and Avalanche Research, Flüelastrasse 11,
7260 Davos, Switzerland
e-mail: c.rheinberger@gmx.net

1 Introduction

Alpine countries invest large amounts of money to safeguard roads and settlements from natural hazards. Switzerland, for example, spends approximately 0.6% of its annual GDP on the mitigation of, and the recovery from, natural hazards (PLANAT 2005). While these efforts are partly financed through private sources, public expenditures cover the lion's share. Publicly funded mitigation programs have so far been focused on the cost-efficient supply of mitigation. An optimal resource allocation would, however, not only consider the supply side but also the societal demand for safety improvements.

Stated preferences provide an operational basis to deduce the societal demand for safety improvements. Yet, only few empirical studies have addressed these preferences in the context of natural hazards.[1] Brouwer and Bateman (2005) studied society's valuation of flood control measures in the Netherlands, Zhai and Ikeda (2006) analyzed the economic value of evacuations during flood events in Japan, and Leiter and Pruckner (2009) estimated the societal willingness-to-pay (WTP) for reductions in avalanche risk in Austria. All of these studies employed the contingent valuation approach to elicit WTP measures for risk reductions.

We contribute to the *economics of natural hazards* literature by presenting a choice experiment (CE) that deals with safety improvements on Alpine roads. Users of these roads are threatened by natural hazards such as avalanches and rockfalls while they also face the risks of accidents caused by poor road conditions, fall hazards along steep slopes or dangerous behavior of other drivers. Our CE confronts survey respondents with discrete choices from among a set of safety programs that provide protection from natural or man-made hazards to reduce mortality risks on Alpine roads.

Three research objectives guide our study. First, we want to find out how much society is willing to pay for reductions in mortality risk on roads in the Swiss Alps. It has been shown that the CE approach is well-suited to study society's preferences for mortality risk reductions and even allows individuating these preferences (Alberini et al. 2007; Itaoka et al. 2006). Based on the CE, we estimate the value of statistical life (VSL), which has become the common metric to value environmental regulations and programs reducing risk to human life (Hammitt 2000).

Second, psychometric research suggests that characteristics such as voluntariness, controllability, and origin affect people's perception of a hazard (Slovic et al. 2000). Presumably, these factors affect the economic valuation of mortality risk reductions but there is relatively little empirical evidence for these effects (Chilton et al. 2006; Leiter and Pruckner 2009). To broaden this evidence, we analyze how characteristics of the hypothetical safety programs and their perceived benefits affect the size of the VSL estimate.

Third, there is an ongoing discussion as to whether the VSL should be individuated according to age (Johansson 2002), wealth (Pratt and Zeckhauser 1996), or baseline risk (Eeckhoudt and Hammitt 2001). We therefore study how people differ in their WTP for risk reductions based on socio-economic characteristics and individual risk exposure. In other words, we analyze preference heterogeneity in the context of mortality risks using the mixed logit model for panel data, as introduced by (Revelt and Train 1998), to account for correlations in unobserved utility over repeated choices by each CE participant.

The paper is organized as follows. Section 2 gives a brief overview of mortality risks on Alpine roads and compares these risks to other causes of death. We then describe the design of our survey, including the attributes and levels selected to characterize the choice tasks,

[1] By this term we refer to naturally occurring events that have a negative effect on a limited number of people. We do not refer to extremely rare disaster events that affect hundreds of thousands of people.

and summarize the characteristics of the respondents. In Sect. 3, we deduce the VSL within the random utility framework and explain our modeling approach to analyze heterogeneous preferences for mortality risk reductions. Selected results of the model estimations as well as scope and robustness tests are presented in Sect. 4. In Sect. 5, we draw some conclusions for the valuation of mortality risk reductions in the public goods context.

2 Survey Design and Sample Characteristics

2.1 Overview of Mortality Risks on Alpine Roads

Alpine roads are frequently exposed to natural hazards—most prominently to avalanches and rockfalls. Within the past 15 years, three individuals per year have been killed on average in accidents caused either by rockfall or avalanche incidents on Swiss roads, while approximately 500 individuals per year have died in car accidents (BFS 2009).

Comparative to other causes of death, the probabilistic risk of dying in such an accident is small (Fig. 1). Yet, many people experience feelings of dread when considering the risks from natural hazards since they are involuntarily borne and out of self-control (Slovic et al. 2000). Dread has been found to be a perceptional factor that tends to increase the WTP for risk reduction (Chilton et al. 2006; Leiter and Pruckner 2009). In comparison, car accidents pose well-known risks that are frequently analyzed in VSL studies (De Blaeij et al. 2003). In our survey, we used car accidents as a reference risk to see whether perceptional factors of natural hazards decrease or increase the societal WTP for safety on Alpine roads.

Since the individual risk of dying in a rockfall or avalanche accident is small and the occurrence of such accidents is hardly predictable, it is a priori unknown whose life will be saved by the implementation of a safety program. Anybody traveling on Alpine roads may potentially benefit from the risk reduction and, as far as public roads are concerned, no one can be excluded from this benefit. Thus, traffic safety on Alpine roads is a public good.

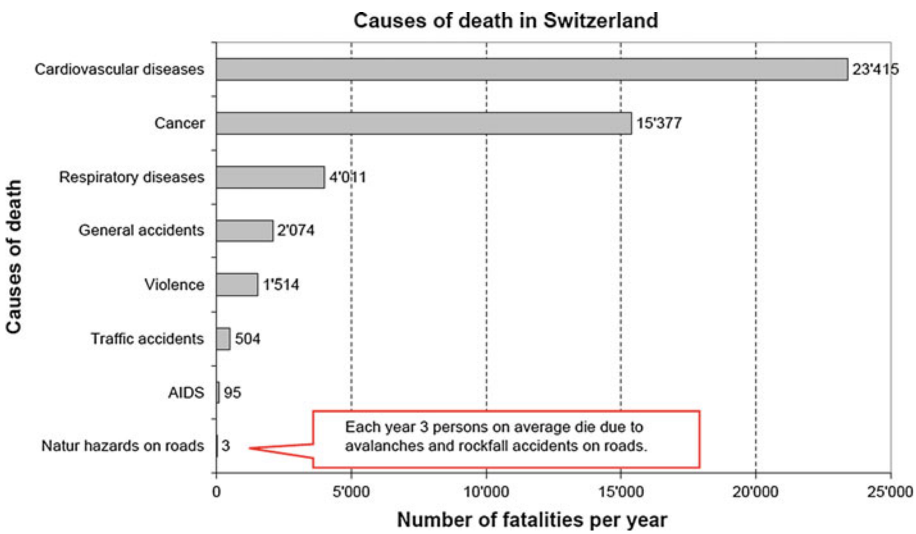

Fig. 1 League table of statistical causes of death in Switzerland (compiled from BFS (2009))

The valuation of mortality risk reductions in the public goods context implies three major challenges. First, the respondent's WTP for risk reduction depends on the magnitude of risk reduction that the respondent thinks of when evaluating the choice tasks (Corso et al. 2001). Second, the magnitude of the cost figures might be used as a mental anchor. Green et al. (1998) showed that the anchoring of prompted costs systematically influences responses in stated-preference studies. This can cause biases in the valuation of public goods, particularly if respondents have strategic incentives to over- or understate their true WTP. Third, respondents may have preferences for reductions in their own risk, in the risk to others, or in expressing mercy and solidarity with people exposed to a risk (Jones-Lee 1991; Viscusi et al. 1988).

We addressed the former two challenges by making the survey instrument as realistic as possible. We presented the risk reduction as a hypothetical referendum for financing the future maintenance of hazard mitigating infrastructure and clearly stated how many fatalities each safety program could avert at which cost. To reduce strategic answering, we used a relative bid vehicle that individualized the cost of each of the alternative programs relative to a percentage of the respondent's last tax payment.

The advantage of this relative bid vehicle is that, when converted to absolute values, it corresponds to the cost incurred to the respondent if the program were to be implemented (Schläpfer 2008). This makes the choice task more realistic and allows us to test for systematic over- or understatement of WTP by comparing the distribution of the stated tax payments by the sample population and the actual distribution of the Swiss tax revenue.[2]

The third challenge can hardly be resolved because respondents' preferences may be composed of self-interested and altruistic motives (Jones-Lee 1991). In our study context, the individual risk is small and the benefits of the proposed safety programs are concentrated on the most exposed people. To avoid aggregation problems induced by different forms of altruism, we explicitly stated in the survey that, if the majority were to decide for a program, everyone would have to take a share in its financing. Furthermore, we approached respondents from two different regions of Switzerland. One sample consisted of mountain dwellers living in the region of Davos where drivers are frequently exposed to natural hazards, while the other consisted of respondents from the city of Zurich who are less likely to be exposed. This split sample approach allows us to test whether less exposed respondents reveal concerns about the safety of others.

2.2 Choice Attributes and Levels

In the design phase of the study, four focus groups with participants from both sample regions were held to explore the relevant attributes of traffic safety on Alpine roads, the understanding of the relative bid vehicle, and the use of various risk communication aids (see Corso et al. 2001). The exploratory research also assisted in specifying the levels of each of the relevant attributes so that respondents could understand improvements in safety as a result of changes in attribute levels. To this end, we discussed the current protection of Alpine roads from natural hazards with a number of experts consisting of representatives of the responsible authorities, civil engineers, and avalanche scientists. These expert interviews provided a semi-quantitative assessment of the current level of safety on Alpine roads, upon which

[2] In our CE, respondents stated slightly higher tax payments than the Swiss population paid in 2007 suggesting no systematic over- or understatement of WTP (see Table 2).

Table 1 Attributes and attribute levels in the discrete choice tasks

Attribute	Levels of the attribute
(1) Number of avoided fatalities per year	10, 12, 14, 16
(2) Duration of protection in years	10, 20, 30
(3) Type of road hazard	Snow avalanches, rockfalls, ordinary car accidents
(4) Relative costs of the program as percentage of the respondent's last tax payment	1%, 2%, 3%

we developed 'what-if' scenarios for the case that mitigation measures would no longer be maintained.

The exploratory research resulted in the selection of four attributes to describe safety programs for Alpine roads: (1) the number of fatalities per year that are averted by a specific program; (2) the number of years over which the program would reduce the risk; (3) the type of hazard against which the program is effective; and (4) the cost of the program to the taxpayer. Table 1 summarizes the selected attributes and levels used in the CE.

Attribute (1) describes the benefit of the safety programs in terms of averted fatalities. Based on the expert interviews, we assumed that the number of fatalities caused by natural hazards on Alpine roads would increase to 20 fatalities per year if current mitigation measures were no longer maintained, but could be kept at the current level if these measures were maintained into the future. Levels of the risk reduction were thus selected at 10, 12, 14, and 16 averted fatalities per year.

Attribute (2) captures the permanence of the risk reduction. We attempted to suggest realistic periods of mitigation benefits based upon the life expectancy of different mitigation infrastructures to protect roads. In the focus groups, we observed that participants had difficulties in calculating the total number of averted fatalities over the proposed period of mitigation benefits. We therefore decided against presenting different mitigation periods between choice alternatives, but changed the period of mitigation between choice sets.

Attribute (3) appoints the type of hazard against which protection is provided. Avalanches and rockfalls were selected as the natural hazards that endanger traffic on Alpine roads, while car accidents were chosen as a reference risk to test for perceptional factors associated with natural hazards. We explained that car accidents on Alpine roads can be caused by fall hazards, blind curves, weak crash barriers, or speeding of other drivers to avoid emphasizing the self-controlled factors of driving.

Attribute (4) names the cost of each safety program by describing it as a onetime payment proportional to the respondents' last annual tax payment. We provided respondents with a conversion table through which they could easily derive their individualized cost-sharing for each of the programs. Married respondents, who have a joint tax invoice, were asked to divide their last tax payment by two in order to derive their individualized cost for each program.

Two premises determined the size of the relative bids. First, the aggregated bids should cover future expenditures for maintaining the protection of cantonal and communal roads against avalanches and rockfalls over the next 30 years. Second, the prompted bid amounts should allow for a large range of possible VSL values (Alberini et al. 2007). To comply with these validity requirements, we recalculated past expenditures for safety on Alpine roads (BFS 2009; PLANAT 2005). Assuming that annual expenditures on road safety will remain at the current level over the next 30 years, their present value will be about CHF 0.5–1 billion, or 1.2–2.4% of the annual tax revenue in Switzerland (BFS 2009).[3] Consequently, the relative bid sizes were selected as 1, 2, and 3% of the respondents' last tax payment.

Taking the average annual per capita tax payment of CHF 5,400 (BFS 2009), the relative bids translate into onetime payments of CHF 54, CHF 108, and CHF 162.[4] Using the basic VSL model outlined in Sect. 3 and assuming discount rates for mortality risks between 0 and 15% (Viscusi and Aldy 2003), the absolute bids for the average taxpayer imply a VSL in the range of CHF 0.3–6.3 million; the absolute bids for the highest tax class imply a VSL in the range of CHF 0.8–20.9 million; and the absolute bids for the lowest tax class imply a VSL in the range of CHF 0.1–2.3 million. These ranges are in line with values found in recent meta-analyses of VSL estimates (Kochi et al. 2006; Viscusi and Aldy 2003).

2.3 Survey Structure

We developed a mail survey consisting of five parts to collect the data. The first part opened with some attitudinal questions about the perception of natural hazards in general and their perceived threat to roads in particular. In the second part, respondents were asked to balance infrequent and severe avalanche accidents against frequent but less severe avalanche accidents. The third part contained the actual choice task, which prompted respondents to consider the introduction of a private fee for maintaining current mitigation measures against rockfall, avalanche and car accidents on cantonal and communal roads in the Swiss Alps.

We introduced the choice task by stating that today only three individuals die each year in rockfall and avalanche accidents on roads, but that this number could rise to 20 fatalities per year if mitigation measures would no longer be maintained. Respondents were presented with the league table of annual mortality causes depicted in Fig. 1 to better understand the mortality risks involved with avalanche, rockfall and car accidents and to align these risks with other causes of death (this was the risk communication aid preferred by participants of our focus group research). Respondents were then asked to imagine a national referendum for financing a safety program. They were told that every household would have to make a onetime payment on condition that the referendum was passed.[5]

The alternative safety programs were presented within six choice sets. For each choice set, respondents had to indicate which of three options they prefer: program A, program B, or neither program. The last option was a conditional status quo, whose choice implied the acceptance of a rise in fatalities from the current three, up to 20 per year. Since we selected three attributes with three levels and one attribute with four levels for describing the programs, $108(= 3^3 \times 4)$ different safety programs were possible. Consequently, a full factorial design would have resulted in 1,944 different choice sets with a constant time attribute across the alternative safety programs. Instead, we used a shifted orthogonal experimental design built from conventional fractional factorials for linear models to reduce the number of choice sets (Louviere et al. 2000).

Based on this experimental design, we generated 54 pairs of alternative safety programs segmented into nine orthogonal blocks of six choice sets. According to Ferrini and Scarpa

[3] We assumed a discount rate of 1.5% based on the inflation-adjusted ten-year spot interest rate on Swiss Confederation bonds.

[4] At the time of the data collection one Swiss franc corresponded to €0.65.

[5] Given this description of our choice task, we do not elicit people's WTP for a reduction in their current risk. Rather we ask them what they would be willing to pay to return to the current risk level after a change in risk occurred. In theoretical terms, we seek to measure equivalent variation rather than compensating variation (see Knetsch 2010).

(2007) this design is appropriate when there is a high degree of uncertainty about the conditions that finally generate the choice-based dataset. The outlined procedure resulted in nine survey versions, each of which contained six different choice sets. A random half of the respondents received the choice sets in reversed order to account for potential learning and fatigue effects.

As a further means for scope testing, we used two survey versions with different but logically equivalent risk framings (see the Appendix). A random half of the respondents received choice sets in which the risk reduction was related to the overall population size of Switzerland. This is an intuitive reference value as it allows respondents to draw comparisons to other spheres of life. The other half received choice sets in which the risk reduction was related to the annual number of road fatalities in Switzerland. The latter framing is in line with the request of the NOAA panel on contingent valuation to describe prompted attributes in stated-preference studies as precisely as possible (Arrow et al. 1993).

Subsequent to the choice task, the survey posed debriefing questions asking respondents to indicate how sure they felt when making their choices and whether they had applied specific decision heuristics. The survey closed with questions about socio-economic characteristics.

2.4 Respondents

The survey was mailed to 900 individuals who had agreed in a previous phone recruitment to participate in the study. The sample was stratified by gender and age to roughly reflect the composition of the Swiss residential population. Half of the respondents were recruited in the region of Davos (mountain subsample) and the other half in the city of Zurich (city subsample). We required respondents to be at least 18 years old, which is the minimum age for voting and for obtaining a driver's license in Switzerland.

The data collection took place between November 2007 and January 2008. The return rate for the survey was 55% ($N = 493$). For the choice analysis, we discarded responses from individuals who (i) did not answer at least four choice sets ($N = 60$); who (ii) chose only program A or only program B, even when this was inconsistent with their earlier choices ($N = 4$); and who (iii) did not provide the socio-economic characteristics necessary to estimate interaction models as presented below ($N = 27$). The data cleaning left us with 2,388 choices from 402 respondents, which corresponds to a response rate of 45%.

Table 2 compares the socio-economic characteristics of the respondents to those of the Swiss residential population. In summary, there is a reasonable match between survey participants and the census data. There is a good representation of all age groups, even though respondents older than 69 years are slightly underrepresented. With regard to the last tax payment, there is some undersampling of the lowest income group. This correlates with the observation that the sample contains somewhat fewer respondents with only primary education. Looking at the stated tax payments, we do not find indication for considerable WTP under- or overstatement.

Chi-square independence tests revealed no significant differences between the two subsamples with respect to gender ($\chi^2_{\langle 1\rangle} = 0.09$; $P = 0.76$), age ($\chi^2_{\langle 69\rangle} = 75.6$; $P = 0.27$), last tax payment ($\chi^2_{\langle 5\rangle} = 2.34$; $P = 0.80$), and employment status ($\chi^2_{\langle 4\rangle} = 0.35$; $P = 0.99$). We found differences with regard to education ($\chi^2_{\langle 4\rangle} = 28.02$; $P < 0.001$) with more city dwellers having attended university. The subsamples differed significantly in their exposure to Alpine road hazards. Only 5.4% of the city dwellers stated that they travel once or more per week on Alpine roads, while 84.8% of the mountain dwellers did so. Based on the self-declared exposure and census data (BFS 2009), we defined the baseline population at risk as those

Table 2 Comparison of the sample characteristics to Swiss census data (BFS 2009)

Variable	Study sample [$N = 402$] (%)	Swiss population (%)
Respondents		
Mountain sample	49.3	–
City sample	50.7	–
Gender		
Women	49.3	52.0
Men	50.7	48.0
Age		
18–29	14.9	17.0
30–39	18.2	15.5
40–49	27.6	19.4
50–59	14.4	16.9
60 or older	24.9	31.1
Annual tax payments[a]		
CHF 2,000 or less	15.0	27
CHF 2,000–6,000	36.2	36
CHF 6,000–10,000	27.2	16
CHF 10,000–14,000	8.9	12
CHF 14,000–18,000	4.2	2
More than CHF 18,000	8.6	7
Educational attainment		
Primary education	2.8	13.3
Secondary education	12.3	8.3
University education	25.2	23.1
Apprenticeship	43.8	45.0
Craftsman's diploma	15.9	10.3

[a] Population shares approximated based on the distribution of the direct federal tax revenue (BFS 2009)

2 million individuals who drive more than once a week on Alpine roads. As described below, we used this figure to quantify the annual statistical mortality risk reduction provided by each safety program.

3 Econometric Model

3.1 Random Utility Theory and the Mixed Logit Model

CE models are founded in random utility theory (see McFadden 2001). Applied to the case of mortality risks on Alpine roads, random utility theory assumes that the unobserved utility of a safety program j can be split into a deterministic component expressed by the indirect utility function V and a random component ε that captures unobservable decision shortcuts used by respondent$i$ to evaluate the program j. The utility derived from program j is determined by the program's attributes and the characteristics of respondent i. Let $\mathbf{X}_{ij}$ denote a vector of explanatory variables describing program j and respondent i, and β denote the corresponding vector of coefficients. Then, the random utility gained by respondent i from choosing program j in a particular choice task q may be written as:

$$U_{ijq} = V(\mathrm{X}_{ijq}; \beta) + \varepsilon_{ijq} = V_{ijq} + \varepsilon_{ijq}, \tag{1}$$

where ε_{ijq} is a random component of an unknown distribution.

The dichotomy of the random utility model allows a decision framework to be constructed by assuming that respondent i prefers a specific safety program k, if the utility entailed by this program is larger than that of any alternative program j. Formally, the probability of choosing program k over any other program j in choice task q is given by:

$$P_{ikq} = \Pr\left[V_{ikq} + \varepsilon_{ikq} > V_{ijq} + \varepsilon_{ijq}, \forall j \neq k\right]. \tag{2}$$

Based on distributional assumptions on the random component, several specifications of the random utility model have been proposed. When the random component is assumed to be independently and identically drawn from a Type-I extreme value distribution, the probability that respondent i chooses program k in choice task q becomes conditional logit:

$$L_{ikq} = \exp\left[\lambda V\left(\mathrm{X}_{ikq}; \beta\right)\right] \Big/ \sum_{\forall j \in J} \exp\left[\lambda V\left(\mathrm{X}_{ijq}; \beta\right)\right], \tag{3}$$

where λ is a scale parameter that may vary over subsets of the sample implying non-constant error variance (Louviere et al. 2000). In the empirical analysis, we followed Campbell et al. (2008) approach and specified scale parameters for four subsets of the sample to test whether the framing of the risk reduction or the origin of the respondent have an effect on the error variance: $\lambda_1 =$ city sample $\cap$ risk framing 1; $\lambda_2 =$ city sample $\cap$ risk framing 2; $\lambda_3 =$ mountain sample $\cap$ risk framing 1; $\lambda_4 =$ mountain sample $\cap$ risk framing 2. In the estimation process, we normalized λ_4 to one and allow the scale parameters of the other three subsets to freely vary.

While the conditional logit model can handle scale heterogeneity, it does not account for preference heterogeneity across respondents or for unobserved correlations across repeated choices. To capture preference heterogeneity we employed a mixed logit model for panel data (Revelt and Train 1998) that treats the vector of coefficients as varying over respondents, i.e. β_i, but constant over the $q = \{1, \ldots, Q\}$ choice tasks that each respondent is engaged with. Consider a sequence of choices $\mathbf{k} = \{k_1, \ldots, k_Q\}$. Conditional on distributional assumptions about β_i, the probability that respondent i makes this particular sequence of choices is a product of logits:

$$\mathbf{L}_{i\mathbf{k}}\left(\beta_i\right) = \prod_{q=1}^{Q} \left(\exp\left[\lambda V\left(\mathrm{X}_{ik_q q}; \beta_i\right)\right] \Big/ \sum_{\forall j \in J} \exp\left[\lambda V\left(\mathrm{X}_{ijq}; \beta_i\right)\right] \right). \tag{4}$$

Since the random component is assumed to be independent over the choices of one respondent, the unconditional probability for a particular sequence of choices is the integral of this product over all values of β_i:

$$P_{i\mathbf{k}}(\theta) = \int \mathbf{L}_{i\mathbf{k}}\left(\beta_i\right) f\left(\beta_i | \theta\right) \, \mathrm{d}\beta_i, \tag{5}$$

with $f(\beta_i|\theta)$ representing the joint density of the mixing distribution conditional on the parameters of this distribution denoted by θ. As Train (2003) notes, there are two concepts of parameters in this model. The coefficient vector β_i represents the parameters associated with respondent i, describing his or her preferences, while the parameters θ define the mixing distribution $f(\beta_i)$ of these preference parameters for the population of respondents.

In the empirical analysis, we seek to estimate the population parameters θ that describe the distribution of the preference parameters. To this end, we have to make assumptions about the distributional forms of the random coefficients. We assume triangular distributions whose means are constrained to equal their spreads, so that the parameters have the same sign across respondents and excessively large coefficients and standard errors can be avoided. Since the integral in Eq. 5 has no closed form, we used simulations based on 500 Halton draws to approximate $P_{i\mathbf{k}}(\theta)$ and then maximized the simulated log-likelihood of the observed choices. The theoretical assumptions of this procedure are outlined in detail in Train (2003). All estimations were made in BIOGEME 1.8 (Bierlaire 2003).

3.2 Estimating the VSL from Discrete Choice Data

The estimation of the VSL within the outlined random parameter logit model requires the specification of the indirect utility function. In our study, the utility of any safety program j depends on its risk reduction R_j and its cost C_{ij}, which varies between respondents due to the use of the relative bid vehicle. Characteristics of the safety program j, denoted by the vector $\mathbf{W}_j$, and of the respondent i, denoted by the vector $\mathbf{Z}_i$, may also determine utility. Since not all of these covariates vary over the repeated choices of an individual, their vectors have to be interacted with either the risk or the cost variable. This obtains a generic form of the indirect utility function:

$$V_{ij} = R_j \left(\alpha_i + \mathbf{Z}_i \boldsymbol{\alpha}_{\mathbf{Z}} + \mathbf{W}_j \boldsymbol{\alpha}_{\mathbf{W}}\right) + C_{ij} \left(\beta_i + \mathbf{Z}_i \boldsymbol{\beta}_{\mathbf{Z}} + \mathbf{W}_j \boldsymbol{\beta}_{\mathbf{W}}\right), \tag{6}$$

where α_i and β_i are random coefficients on the risk and cost parameter, and $\boldsymbol{\alpha}_{\mathbf{Z}}$, $\boldsymbol{\alpha}_{\mathbf{W}}$, $\boldsymbol{\beta}_{\mathbf{Z}}$, $\boldsymbol{\beta}_{\mathbf{W}}$ are vectors of fixed coefficients on interactions between these parameters and specified covariates.

The design of our choice task required some additional specifications. While the cost C_{ij} of each program j was implemented as a onetime payment, its potential risk reduction was described as a stream of annual risk reductions provided over the period of mitigation T_j. We assumed exponential discounting to compute the discounted stream of risk reduction R_j:

$$R_j = \int_0^{T_j} \pi_j \exp(-\delta t) \mathrm{d}t = \pi_j \left[1 - \exp(-\delta T_j)\right] / \delta, \tag{7}$$

where δ is the implicit discount rate and π_j denotes the annual risk reduction by program j.[6] By inserting Eq. 7 into Eq. 6, the discount rate δ can be directly estimated from the choice data.

6 Alternatively, we explored a hyperbolic discounting regime assuming that $R_j = \pi_j[ln(\delta T + 1)]/\delta$. Estimations with the hyperbolic discounting regime resulted in insignificant coefficients on the discount rate and implied a VSL about double the size of the estimates obtained under exponential discounting (results are available upon request). Since the hyperbolic discounting models had a significantly worse fit, we limit the discussion in the result section to estimates obtained by exponential discounting.

In line with Alberini et al. (2007), we denote respondent i's marginal utility of risk reduction by the compound coefficient vector $\boldsymbol{\alpha}_i = \left(\breve{\alpha}_i + \mathbf{Z}_i\boldsymbol{\alpha}_\mathbf{Z} + \mathbf{W}_j\boldsymbol{\alpha}_\mathbf{W}\right)$ and the marginal utility of wealth by the compound coefficient vector $\boldsymbol{\beta}_i = \left(\breve{\beta}_i + \mathbf{Z}_i\boldsymbol{\beta}_\mathbf{Z} + \mathbf{W}_j\boldsymbol{\beta}_\mathbf{W}\right)$, where $\breve{\alpha}_i$ and $\breve{\beta}_i$ are simulated realizations of the random coefficients. Since the VSL is defined as the WTP for a marginal decrement in risk, it equals the ratio of the averaged coefficient vectors, i.e. $\mathrm{VSL}_i \equiv \left(\partial V_{ij}/\partial R_j\right) / \left(\partial V_{ij}/\partial C_{ij}\right) = \bar{\boldsymbol{\alpha}}_i/\bar{\boldsymbol{\beta}}_i$. In the result section, we make extensive use of this relationship.

4 Results

4.1 Qualitative Results

Respondents had relatively homogenous attitudes toward natural hazards and their threat to Alpine roads. When asked about their risk of being killed by an avalanche or a rockfall, 69% felt barely endangered, 27% felt somewhat endangered, 2% felt strongly endangered, and 2% found it hard to tell. When comparing the risks of natural hazards with other road hazards, 84% found the latter more threatening, 11% found both risks equally threatening, 3% found natural hazards more threatening, and 2% found it hard to tell. With regard to current protection against avalanches and rockfalls, 67% stated that Alpine roads are sufficiently protected while 33% wished better protection. Answers to these questions did not statistically differ between the subsamples.

We examined the choice frequencies for safety programs that provide protection from the different types of hazard. Neither program was chosen in 20.9% of the choice sets, which suggests that respondents did not reject the programs without due consideration. The choice frequency of programs that provide protection from rockfalls (28.0%) was slightly higher than for programs that provide protection from car accidents (26.3%) or avalanches (24.8%).

4.2 The Basic VSL Model

In the next subsections, we report on selected results of our choice analysis. We begin by presenting estimates of the basic model that includes only the individualized cost, the discounted risk reduction and the discount rate as explanatory variables (Model I in Table 3).

The coefficients on these preference parameters are significant and have the expected signs. The coefficient of the random risk parameter is positive indicating that the respondents valued risk reductions as a benefit, while the coefficient of the random cost parameter is negative showing that spending private money on public safety programs entails a disutility. The implied discount rate was pegged at 10.9%, which is in the upper range of discount rates reported in market-based VSL studies (Viscusi and Aldy 2003). The coefficients on the scale parameters are not significant in either this basic model or in any of the more sophisticated models. We conclude that, if there is heterogeneity in the error variance, it can neither be attributed to the framing of the risk reduction nor to the origin of respondents.

The coefficients on the preference parameters in Model I allow the estimation of the VSL. Since the model assumes both the risk reduction and the costs to be subject to preference heterogeneity, the mean VSL has to be estimated via the simulation of its distribution. Following the procedure outlined in Thiene and Scarpa (2009), we simulated both random parameters by 10,000 independent draws from constrained triangular distributions. This simulation yielded

Table 3 Mixed logit model results of Models I–III

Parameters	Model I		Model II		Model III	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Preference parameters						
Mean of risk parameter	0.0505	6.39	0.0461	5.95	0.0465	5.96
Spread of risk parameter	0.0505	6.39	0.0461	5.95	0.0465	5.96
Mean of cost parameter	−0.0088	−5.58	−0.0270[†]	−9.45	−0.0461[†]	−3.88
Spread of cost parameter	0.0088	5.58				
Coefficient of relative risk aversion			1.0000	Fixed	1.6620	6.29
Discount rate	0.1094	6.23	0.1152	5.17	0.1151	5.19
Interactions with preference parameters						
Utility of wealth[a]			0.0080	8.10	0.0325	1.88
Scale parameters						
λ_1: city sample ∩ risk framing related to Swiss population	0.8497	−1.13	0.9542	−0.38	0.9595	−0.33
λ_2: city sample ∩ risk framing related to annual road fatalities	1.0570	0.36	0.9920	−0.06	0.9795	−0.17
λ_3: mountain sample ∩ risk framing related to Swiss population	1.0690	0.44	1.1480	1.05	1.1360	0.98
λ_4: mountain sample ∩ risk framing related to annual road fatalities	1.0000	Fixed	1.0000	Fixed	1.0000	Fixed
Model summary						
Number of choices	2,388		2,388		2,388	
Number of respondents	402		402		402	
Log-likelihood function	−1,838.85		−1,917.64		−1,914.98	
Likelihood ratio test	1,569.27		1,411.69		1,417.01	
Adjusted Pseudo-R^2	0.296		0.266		0.267	

[a] Interaction with the cost parameter; [†] Non-random parameter

a VSL distribution with a mean of CHF 7.8 million, a lower quintile of CHF 1.7 million and an upper quintile of CHF 19.7 million. The median VSL value was CHF 5.7 million.

4.3 The Effect of Wealth on the VSL

Economic theory suggests that the VSL increases with wealth.[7] Hammitt and Treich (2007) provide two reasons for this effect. First, wealthier people lose more in absolute terms when they die. Second, their utility cost of spending is smaller due to the standard assumption of

[7] We draw on the definition of the VSL as the marginal rate of substitution between wealth and mortality risk to prove this assertion. The standard model defines the VSL as $\frac{dw}{dp} = \frac{u(w)-v(w)}{(1-p)u\prime(w)+pv\prime(w)}$, where p is the individual's probability of dying during a defined period and $u(w)$ and $v(w)$ denote utility derived from wealth w conditional on surviving or dying in that period. (Primes indicate first derivatives with respect to wealth.) Some common assumptions on the utility functions are (Hammitt 2000): (i) survival is preferred to death: $u(w) > v(w)$; (ii) the marginal utility of wealth is non-negative and greater in life than in death: $u'(w) > v'(w) = 0$; and (iii) individuals are risk averse with respect to wealth: $u“(w) = 0$, $v''(w) = 0$. Under these assumptions, the first derivative of the VSL with respect to wealth is positive ($\partial VSL/\partial w > 0$) and the second derivative is non-negative ($\partial^2 VSL/\partial w^2 = 0$).

decreasing marginal utility with respect to wealth. Our relative bid vehicle allows exploration of how the VSL varies with wealth.

To test for the alleged wealth effect, we extended Model I by an interaction between the individualized cost of the safety program C_{ij} and the utility of wealth. In accordance with the assumptions imposed in Footnote 7, we used an isoelastic function of the respondent's last tax payment τ_i as representation of his or her utility of wealth:

$$V_{ij} = \alpha_i R_j + \beta C_{ij} + \varphi C_{ij}[(1-\eta)^{-1}(\tau_i^{1-\eta} - 1)], \tag{8}$$

where η denotes the respondent's coefficient of relative risk aversion. The last term in Eq. 8 captures the difference between how much wealthier people and poorer people are willing to pay relative to their wealth status. Table 3 presents estimates of this model assuming that $\eta = 1$ (Model II), which implies that utility is logarithmic, or that η is estimated via full information maximum likelihood (Model III). In both models, non-random parameters were used for the cost (β) and the utility of wealth (φ) to ensure that wealth-specific WTP was non-negative.

In line with theoretical expectations we find that the VSL increases marginally with wealth ($\partial^2 VSL/\partial\tau_i^2 > 0$). In other words, wealthier respondents are willing to spend relatively more on safety than poorer respondents. Figure 2 depicts how the VSL varies with the size of the last tax payment indicating that, at lower wealth levels, the VSL is relatively inelastic toward changes in safety expenditure. At higher wealth levels, the VSL becomes increasingly elastic. The arc elasticity of the VSL weighted by the share of taxpayers in our sample is 0.96 (Model II) and 0.90 (Model III), respectively. The coefficient of relative risk aversion in Model III is estimated at $\hat{\eta} = 1.66$, confirming that the elasticity of marginal utility increases with wealth.

A note is warranted on the above elasticity measures. Since the Swiss tax law permits deductions that vary with residency and other characteristics unrelated to income and

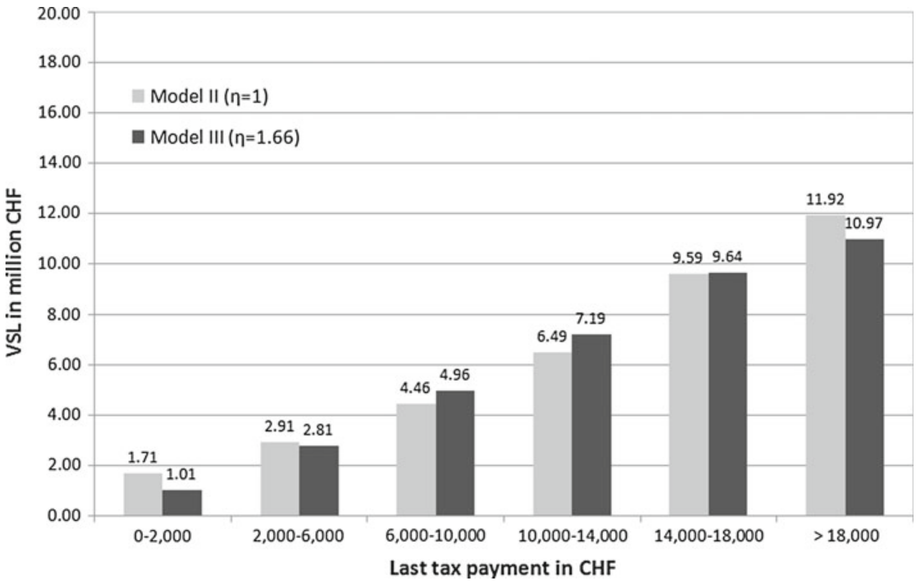

Fig. 2 Wealth-specific VSL estimates based on Models II and III

wealth, the reported elasticity measures cannot be converted one-to-one into income elasticities. Yet, the income elasticities of the majority of respondents should be larger than unity because Switzerland has a progressive tax regime. This empirical observation supports the theoretical findings of Kaplow (2005), who asserts that, under mild assumptions about the coefficient of relative risk aversion, the income elasticity of the VSL should be larger than unity.

4.4 The Effect of Respondent Characteristics on the VSL

Respondent characteristics other than wealth also affect the WTP for traffic safety on Alpine roads. In Table 4, we presents two interaction models (Models IV–V) that identify sources of heterogeneity in preferences for mortality risk reductions and make the VSL contingent upon individual and risk-related characteristics as urged by Sunstein (2004).

Model IV includes several interactions with socio-economic covariates so that the VSL becomes conditional on respondent characteristics. The significant coefficient of the interaction between the sample indicator (mountain sample = 0; city sample = 1) and the risk parameter suggests that, *ceteris paribus*, city dwellers had a 28% higher marginal utility of risk reduction. We offer two possible explanations for this result. First, people familiar with natural hazards may have a higher risk acceptance because they see these risks as part of life in the mountains. Corresponding statements made by focus group participants support this explanation. Second, respondents from the city sample may have altruistic motives that increase their marginal utility of risk reduction although their individual benefit from maintained traffic safety on Alpine roads is smaller than that of mountain dwellers (Jones-Lee 1991). This explanation is backed by several answers to debriefing questions in the survey.

To explore the first explanation, we included two further interaction terms: a two-way interaction between the risk parameter and a dummy indicating whether the respondent attended university; and a three-way interaction between the risk parameter, the university attainment, and the sample indicator. This revealed that university education was associated with a substantially higher marginal utility of risk reduction, but preferences informed by educational attainment differed strongly between the two subsamples. While university education had only a small effect on the preferences of city dwellers, mountain dwellers without university education (41% of all respondents) placed a distinctly lower value on risk reductions than the rest of the respondents. Debriefing questions revealed that these respondents felt entitled to the benefits of mitigation and were therefore not willing to participate in the financing of safety programs.

The interaction between the age of the respondent and the risk parameter indicates a moderate decrease of 1.8% per life year in the marginal utility of risk reductions. This finding is in line with empirical observations that the VSL decreases with age (Viscusi and Aldy 2003) and implies a value of a statistical life-year of about CHF 120,000 (€78,000) for the average-aged individual in the sample.

The interaction between the gender of the respondent and the risk parameter was non-significant. This corresponds with observations by Davidson and Freudenburg (1996) who found that women and men have similar perceptions of most environmental risks. Since, in both samples, men were more likely to have university education, we tested for a three-way interaction effect between gender, risk reduction and education, which turned out to be insignificant. Thus, we conclude that gender differences had no significant effect on the valuation tasks in this study.

Table 4 Mixed logit model results of Models IV and V

Parameters	Model IV		Model V	
	Coeff.	t-ratio	Coeff.	t-ratio
Preference parameters				
Mean of risk parameter	0.0747	5.38	0.0753	5.49
Spread of risk parameter	0.0747	5.38	0.0753	5.49
Mean of cost parameter	−0.0053	−4.29	−0.0067	−4.02
Spread of cost parameter	0.0053	4.29	0.0067	4.02
Discount rate	0.1025	5.10	0.1075	5.21
Interactions with preference parameters				
Age[a]	−0.0013	−4.48	−0.0011	−4.30
Female[a]	0.0012	0.18	0.0054	0.73
University educated[a]	0.0506	2.78	0.0680	3.84
City sample[a]	0.0210	2.31	0.0443	3.14
City sample × university educated[a]	−0.0453	−2.12	−0.0631	−2.86
Avalanche hazard[a]	−0.0031	−1.77	−0.0036	−1.94
Rockfall hazard[a]	0.0011	0.61	0.0008	0.47
Experience with natural hazard[a]			−0.0152	−1.91
Low exposure[a]			−0.0369	−2.52
Risk framing related to Swiss population[a]			−0.0100	−1.33
Perceived safety[b]			0.0067	3.81
Scale parameters				
λ_1: city sample ∩ risk framing related to Swiss population	0.8210	−1.15	0.8577	−0.86
λ_2: city sample ∩ risk framing related to annual road fatalities	1.0104	0.06	1.0030	0.02
λ_3: mountain sample ∩ risk framing related to Swiss population	0.9548	−0.27	0.9509	−0.30
λ_4: mountain sample ∩ risk framing related to annual road fatalities	1.0000	Fixed	1.0000	Fixed
Model summary				
Log-likelihood function	−1,756.16		−1,735.29	
Likelihood ratio test	1,734.65		1,776.39	
Adjusted Pseudo-R^2	0.325		0.331	

[a] Interaction with the risk parameter; [b] Interaction with the cost parameter

4.5 The Effect of Type of Hazard on the VSL

Model IV includes further interaction terms between the type of hazard and the risk parameter. To analyze the effect of the type of hazard on the VSL, we coded car accidents as the reference risk, i.e. negative (positive) coefficients on the avalanche and rockfall dummies in Table 4 imply a decrease (increase) in the perceived risk *compared to* car accidents.

The coefficient on the interaction between the rockfall dummy and the risk parameter was clearly non-significant; the coefficient on the interaction between the avalanche dummy and the risk parameter was barely significant ($p = 0.08$). Even if they were statistically significant, the size of the coefficients was too small to suggest that the perceived risk of natural hazards differs from the perceived risk of car accidents in a way that affects the demand for risk reduction.

We re-estimated the model by aggregating rockfalls and avalanches into one dummy indicating whether a safety program would reduce risk from natural or man-made hazards (results are available upon request). Again, the coefficient on the interaction between this dummy and the risk parameter was not significant. We conclude that a 'dread' premium for natural hazard risks, as urged for particularly frightening, involuntarily borne and uncontrollable risks (Sunstein 2004), seems—at least in the context of Alpine road safety—unjustifiable on empirical grounds.

Since the coefficients on the random risk and cost parameters as well as on the discount rate in Model IV do not differ considerably from the basic VSL model (Model I), we evaluated Model IV at the sample means of covariates obtaining a mean VSL value of CHF 7.8 million. Again, the computation of the random risk and cost parameters was based on 10,000 simulation draws. (Some of these random draws implied negative VSL realizations, which are behaviorally unrealistic. We set them to zero obtaining an upper bound on the mean of the simulated VSL.)

4.6 Scope and Robustness Tests

The validity of stated-preference studies is often challenged by opponents who argue that stated choices are of hypothetical nature and do not relate to real market transactions. It is therefore crucial to test the scope of the above results. Since our respondents made choices involving risk reductions of different size, cost, and duration, these differences should be reflected in the expected economic manner. The basic requirement of scope in VSL studies is that respondents receive a positive marginal utility from reducing risks and a negative marginal utility from spending. In other words, they should be willing to pay for risk reductions, but not at any price.

Our results conform to this requirement, providing VSL estimates well within the range of previous stated-preference studies on mortality risk (Kochi et al. 2006). Heberlein et al. (2005) extended the notion of scope by proposing to also test for attitudinal and behavioral scope. Testing for attitudinal and behavioral scope involves the inclusion of interaction terms between either the risk or the cost parameter and appropriate perceptional factors in order to see whether these factors affect the WTP in the expected attitudinal or behavioral manner.

Applied to mortality risk valuations, attitudinal scope posits that the more threatening respondents perceive a specific risk to be, the more they should be willing to pay for risk reduction. In Model V we explicitly tested for attitudinal scope based on two interaction effects. First, we compared respondents who indicated that current protection of Alpine roads against natural hazards is sufficient with those who wished more protection. With all else equal, the latter respondents were willing to spend 11% more on the proposed safety programs. This indicates that our results are consistent with the presence of attitudinal scope.

Second, we compared respondents who stated that they had been affected by natural hazards in the past with those who reported to have had no experience with natural hazards. The WTP of the latter respondents was 27% higher than that of experienced respondents. Consistent with results from psychometric risk research (Slovic et al. 2000), we reason that respondents acquainted with natural hazards perceived these risks to Alpine roads as less threatening than those who had no individual experiences with natural hazards.

Behavioral scope in mortality risk valuations posits that those who are less exposed to a specific risk should have a lower WTP. This was clearly the case in our experiment, with respondents who stated that they rarely travel on Alpine roads having a VSL only half that of those who stated that they are frequently exposed. Moreover, behavioral scope implies that what is valued by the respondents is the effective risk reduction. Risk framings, as incorporated into our survey instrument, should have only marginal, if any, effect on the valuation of risk reductions. To our satisfaction, we find a statistically insignificant framing effect indicating that respondents did attentively read the description of the safety programs and gave due consideration to the number of lives saved per program.

All other coefficients in Model V are of comparable size to those estimated in Model IV (Table 4). A likelihood ratio test (LRT) shows that the inclusion of the additional interactions did significantly improve the model fit ($\chi^2_{\langle 4\rangle} = 41.74$; $P < 0.001$). Again, we evaluated Model V at the sample means of covariates and obtained a mean VSL value of CHF 7.6 million.

The above analysis provides evidence for attitudinal and behavioral scope in our results. However, scope sensitivity is but one validity criterion of stated-preference studies. Another criterion is the robustness of estimates to changes in the data used in the empirical analysis. To control for the robustness of our estimates, we re-estimated Models I–V by (i) dropping observations from respondents who stated that they feel uncertain about their choices, and (ii) by dropping the first and last observation of every respondent to account for potential effects of learning or fatigue (see Tables 6 and 7 in the Appendix). Neither of these re-estimations altered the broad picture of the presented VSL values, which we take as evidence of the robustness of our estimates against confounding influences of hidden variables (Table 5).

Table 5 Record of the simulated VSL distributions of Models I–V (in million CHF) evaluated at the sample means of covariates

VSL distribution	Model I	Model II	Model III	Model IV[a]	Model V[a]
Original models					
Mean	7.822	6.249	6.025	7.800	7.648
5% percentile	1.666	1.013	0.707	0	0
95% percentile	19.716	15.954	14.743	23.074	21.796
Robustness test 1					
Mean	8.378	6.330	6.073	8.199	8.217
5% percentile	1.784	1.067	0.499	0	0
95% percentile	21.117	15.868	14.269	23.695	23.056
Robustness test 2					
Mean	8.500	5.609	5.414	8.424	8.188
5% percentile	1.811	0.882	0.583	0	0
95% percentile	21.427	14.544	13.371	25.170	23.417

Robustness test 1 re-estimates Models I–V, dropping observations from uncertain respondents; Robustness test 2 drops the first and last observation of every respondent. Simulations are based on 10’000 draws

[a] Negative realizations of simulated VSL values were excluded for deriving means of the VSL distribution

5 Discussion and Conclusions

In this paper we have presented a CE to analyze public preferences for safety on Alpine roads. The prompted tradeoffs between risk and money imply VSL values in the range of CHF 6.0–7.8 million (€3.9–5.1 million), which is in the ballpark of estimates found in other stated-preference studies on mortality risks (Kochi et al. 2006). Our estimates are somewhat larger than the VSL of CHF 5 million (€3.3 million) currently used by the Swiss administration to evaluate traffic safety programs for Alpine roads (PLANAT 2005), but distinctly lower than (inflation adjusted) VSL estimates from a Swiss labor market study (Baranzini and Ferro Luzzi 2001), which are in the range of CHF 10.8–16.2 million (€7.0–10.5 million).

In most western countries, the VSL has become the standard metric to inform policy makers about the costs and benefits of environmental and health risk regulations. However, governmental agencies are reluctant to acknowledge that the VSL is, by concept, not a natural constant but varies across risks and across individuals. To shed some light on these variations we employed a split sample approach, studying two subpopulations that differ with respect to their exposure to natural and man-made hazards on Alpine roads. Since these risks are predominantly borne by frequent road users, we recruited respondents from the mountain region of Davos to represent frequently exposed people and from the city of Zurich to represent rarely exposed people.

Respondents from the mountain sample were *ceteris paribus* willing to pay less for the proposed safety programs, though they would possibly benefit more from the reductions in risk. We offer two explanations for this apparent violation of rational choice behavior. First, we find that among respondents of the mountain sample, those without university education placed a significantly lower value on the marginal utility of risk reduction and refused more often (25% compared to 16%) to make any private contribution to the proposed safety programs than the other respondents. We conclude that the hypothesized withdrawal of public resources for the protection of Alpine roads caused protest behavior by some of the respondents.

Second, earlier research has found that preferences for mortality risk reductions are determined by self-interested and altruistic motives (Jones-Lee 1991; Viscusi et al. 1988). Altruism is a non-use value that is relevant for the economic valuation of mortality risk reductions when individuals are concerned about the safety of others but indifferent with respect to further determinants of welfare (Jones-Lee 1991). While our results suggest the existence of altruistic values for safety on Alpine roads, we cannot ascertain econometrically that these values are driven by paternalistic motives. The analysis of answers to debriefing questions, however, suggests that respondents from the city sample put emphasis on saving lives. On the other hand, we also find evidence for self-interested motives. Respondents who stated that they are rarely exposed had a distinctly lower WTP for risk reduction than those who stated that they are frequently exposed. We conclude that, at the margin, altruistic and self-interested motives might counterbalance each other.

Perceptional factors played an important role in the valuation of the safety programs. Respondents differed in their WTP for risk reduction dependent on whether or not they perceived the current level of protection to be sufficient, and on whether or not they had had experiences with natural hazards. This is not surprising since preferences over levels of goods are made up of the individual's perceptions of these goods (McFadden 2001). This said we would have expected the type of hazard to be of more importance in the valuation because many respondents indicated that they perceive car accidents as the more threatening risk than natural hazards. We conclude that most respondents emphasized the costs and expected risk reductions as key attributes to evaluate the proposed safety programs.

We investigated several other aspects of preference heterogeneity and found that preferences for mortality risk reductions vary with age and educational attainment. Moreover, our survey instrument offered a detailed look at how wealth effects affect the valuation of mortality risks. We discerned wealth-specific VSL values, indicating that the VSL increases over-proportionally with wealth. This finding corresponds with the assumption of a marginally decreasing utility of wealth and supports Sunstein (2004) call for a more individuated VSL based on the observed differences in the actual demand for safety. While many would contest such a practice on ethical grounds, it would reduce the loss in social surplus that arises from overspending on one particular life-saving program by shifting resources to other programs so that the marginal benefit per Swiss franc, euro, or dollar spent will be the same across programs (Tengs et al. 1995).

In sum, our paper supports this call for a VSL that is more aligned to the public's demand for safety. Based on CE data, our mixed logit approach provides evidence for considerable heterogeneity in the public's preferences for mortality risk reductions. Moreover, we are able to identify several sources of preference heterogeneity by interacting respondent characteristics, individual risk perceptions, and safety program attributes. Our findings suggest that the determination of costs and benefits of environmental and health risk regulations should take more account of the preferences of the population at risk. In other words, it might be necessary to withdraw from the idea of a single VSL that can be used to assess welfare impact of safety programs and policies across different contexts of risk and different populations at risk.

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Appendix

See Tables 6, 7 and Fig. 3.

Table 6 Robustness test of Models I–V: Dropping answers of uncertain respondents

Parameters	Model I		Model II		Model III		Model IV		Model V	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Preference parameters										
Mean of risk parameter	0.0453	6.18	0.0439	5.73	0.0446	5.74	0.0670	5.19	0.0662	5.32
Spread of risk parameter	0.0453	6.18	0.0439	5.73	0.0446	5.74	0.0670	5.19	0.0662	5.32
Mean of cost parameter	−0.0074	−5.21	−0.0243†	−8.36	−0.0667†	−3.46	−0.0049	−4.03	−0.0057	−3.83
Spread of cost parameter	0.0074	5.21					0.0049	4.03	0.0057	3.83
Coefficient of relative risk aversion			1.0000	Fixed	2.1497	7.74				
Discount rate	0.0968	5.70	0.1047	4.85	0.1048	4.89	0.0930	4.74	0.0955	4.70
Interactions with preference parameters										
Utility of wealth[b]			0.0071	7.11	0.0743	1.99				
Age[a]							−0.0012	−4.38	−0.0009	−4.09
Female[a]							0.0044	0.65	0.0071	1.01
University educated[a]							0.0412	2.15	0.0587	3.39
City sample[a]							0.0157	1.90	0.0299	2.49
City sample × university educated[a]							−0.0297	−1.38	−0.0424	−2.11
Avalanche hazard[a]									−0.0030	−1.73
Rockfall hazard[a]									0.0020	1.19
Experience with natural hazard[a]									−0.0135	−1.77
Low exposure[a]									−0.0207	−1.84
Framing related risk to Swiss population[a]									−0.0120	−1.67
Perceived safety[b]									0.0059	3.48
Scale parameters										
λ_1 city sample ∩ risk framing 1	0.9267	−0.49	1.0312	0.22	1.0485	0.34	0.8883	−0.65	0.9381	−0.34
λ_2: city sample ∩ risk framing 2	1.1012	0.58	0.9813	−0.14	0.9627	−0.28	1.0172	0.09	1.0319	0.17

Table 6 continued

Parameters	Model I		Model II		Model III		Model IV		Model V	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
λ_3: mountain sample ∩ risk framing 1	1.0654	0.39	1.0971	0.64	1.0958	0.64	0.9224	−0.46	0.9670	−0.20
λ_4: mountain sample ∩ risk framing 2	1.0000	Fixed	1.0000	Fixed	1.0000	Fixed	1.0000	Fixed	1.0000	Fixed
Model summary										
Number of choices		2163		2163		2163		2163		2163
Number of respondents		364		364		364		364		364
Log-likelihood function		−1, 668.42		−1, 721.53		−1, 714.62		−1, 599.82		−1, 582.06
Likelihood ratio test		1,415.75		1,309.53		1,323.35		1,552.96		1,588.48
Adjusted Pseudo-R^2		0.295		0.272		0.275		0.320		0.326

[a] Interaction with the risk parameter; [b] Interaction with the cost parameter; † Non-random parameter

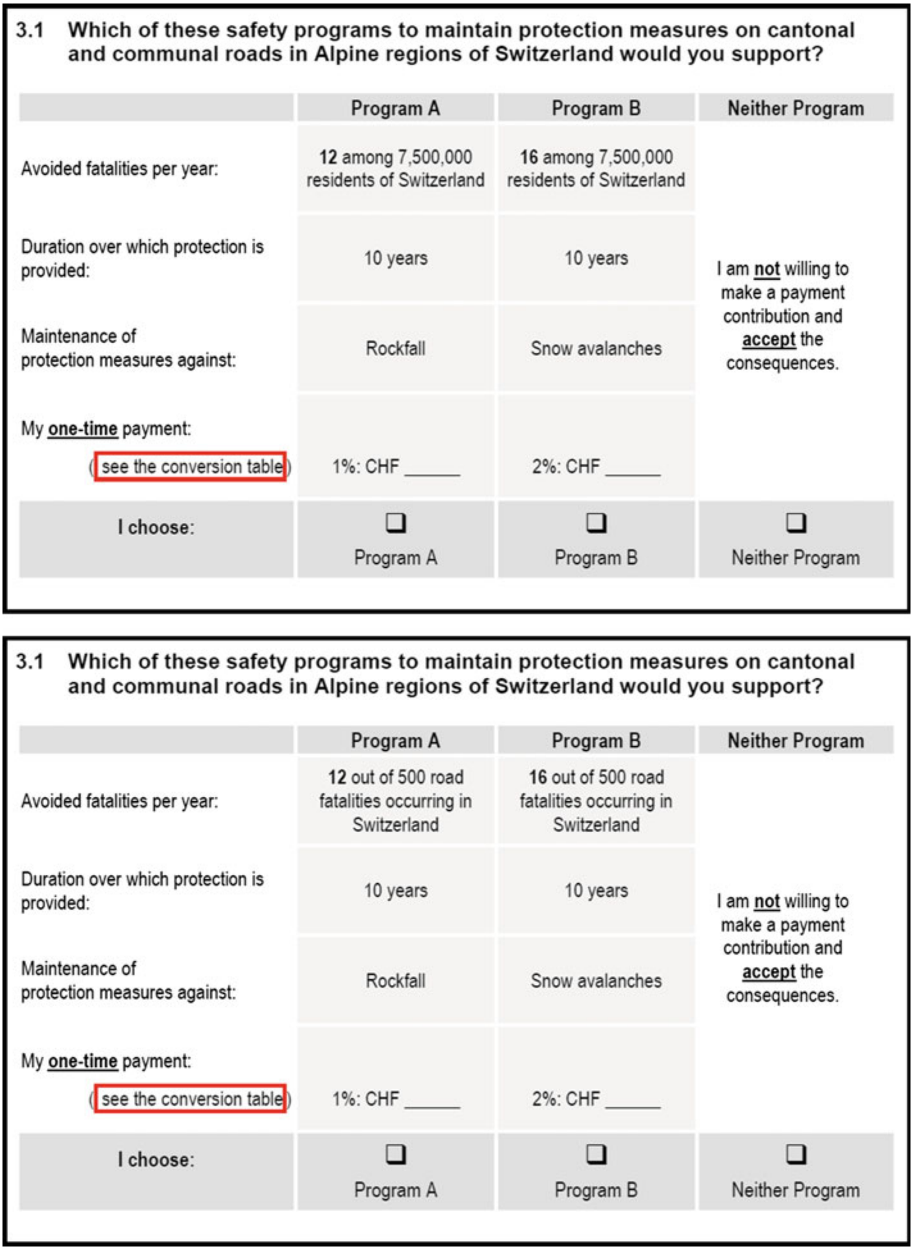
Table 7 Robustness test of Models I-V: Dropping answers to the first and last choice set

Parameters	Model I		Model II		Model III		Model IV		Model V	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Preference parameters										
Mean of risk parameter	0.0496	4.65	0.0414	4.82	0.0418	4.83	0.0729	4.02	0.0722	4.08
Spread of risk parameter	0.0496	4.65	0.0414	4.82	0.0418	4.83	0.0729	4.02	0.0722	4.08
Mean of cost parameter	−0.0080	−4.42	−0.0281†	−7.99	−0.0513†	−3.54	−0.0046	−3.73	−0.0059	−3.46
Spread of cost parameter	0.0080	4.42					0.0046	3.73	0.0059	3.46
Coefficient of relative risk aversion			1.0000	Fixed	1.7293	6.20				
Discount rate	0.1042	4.53	0.1039	4.02	0.1042	4.04	0.1094	3.53	0.1092	3.69
Interactions with preference parameters										
Utility of wealth[b]			0.0084	6.97	0.0390	1.80				
Age[a]							−0.0013	−3.38	−0.0010	−3.17
Female[a]							0.0021	0.25	0.0059	0.63
University educated[a]							0.0466	2.12	0.0613	2.72
City sample[a]							0.0156	1.48	0.0324	1.61
City sample × university educated[a]							−0.0318	−1.27	−0.0432	−1.67
Avalanche hazard[a]									−0.0017	−0.81
Rockfall hazard[a]									0.0018	0.81
Experience with natural hazard[a]									−0.0162	−1.49
Low exposure[a]									−0.0264	−1.38
Framing related risk to Swiss population[a]									−0.0156	−1.45
Perceived safety[b]									0.0062	3.04

Table 7 continued

Parameters	Model I		Model II		Model III		Model IV		Model V	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Scale parameters										
λ_1: city sample ∩ risk framing 1	0.8741	−0.73	1.0568	0.36	1.0757	0.47	0.8802	−0.67	0.8644	−0.71
λ_2: city sample ∩ risk framing 2	0.9954	−0.02	0.9877	−0.08	0.9854	−0.10	0.9933	−0.03	0.9650	−0.16
λ_3: mountain sample ∩ risk framing 1	0.9487	−0.28	1.0531	0.34	1.0444	0.28	0.8923	−0.62	0.9016	−0.55
λ_4: mountain sample ∩ risk framing 2	1.0000	Fixed	1.0000	Fixed	1.0000	Fixed	1.0000	Fixed	1.0000	Fixed
Model summary										
Number of choices		1593		1593		1593		1593		1593
Number of respondents		402		402		402		402		402
Log-likelihood function		−1,283.80		−1,315.97		−1,313.12		−1,228.24		−1,214.33
Likelihood ratio test		932.57		868.24		873.94		1,043.69		1,071.52
Adjusted Pseudo-R^2		0.262		0.244		0.245		0.290		0.295

[a] Interaction with the risk parameter; [b] Interaction with the cost parameter; [†] Non-random parameter



3.1 Which of these safety programs to maintain protection measures on cantonal and communal roads in Alpine regions of Switzerland would you support?

	Program A	Program B	Neither Program
Avoided fatalities per year:	**12** among 7,500,000 residents of Switzerland	**16** among 7,500,000 residents of Switzerland	I am **not** willing to make a payment contribution and **accept** the consequences.
Duration over which protection is provided:	10 years	10 years	
Maintenance of protection measures against:	Rockfall	Snow avalanches	
My **one-time** payment: (see the conversion table)	1%: CHF ______	2%: CHF ______	
I choose:	❑ Program A	❑ Program B	❑ Neither Program

3.1 Which of these safety programs to maintain protection measures on cantonal and communal roads in Alpine regions of Switzerland would you support?

	Program A	Program B	Neither Program
Avoided fatalities per year:	**12** out of 500 road fatalities occurring in Switzerland	**16** out of 500 road fatalities occurring in Switzerland	I am **not** willing to make a payment contribution and **accept** the consequences.
Duration over which protection is provided:	10 years	10 years	
Maintenance of protection measures against:	Rockfall	Snow avalanches	
My **one-time** payment: (see the conversion table)	1%: CHF ______	2%: CHF ______	
I choose:	❑ Program A	❑ Program B	❑ Neither Program

Fig. 3 Example of one choice set describing the risk reduction in reference to either the Swiss residential population (risk framing 1, *upper panel*) or the annual number of Swiss traffic deaths (risk framing 2, *lower panel*)

References

Alberini A, Tonin S, Turvani M et al (2007) Paying for permanence: public preferences for contaminated site cleanup. J Risk Uncertain 34:155–178

Arrow K, Solow R, Portney P et al (1993) Report of the NOAA panel on contingent valuation. Fed Regist 58:4601–4614

Baranzini A, Ferro Luzzi G (2001) The economic value of risks to life: evidence from the Swiss labour market. Swiss J Econ Stat 137:149–170

BFS (2009) Swiss statistical encyclopedia. Published by the Swiss Federal Statistical Office (BFS). http://www.bfs.admin.ch/bfs/portal/en/index/infothek/lexikon.html. Last accessed on: 08/08/2010

Bierlaire M (2003) BIOGEME: A free package for the estimation of discrete choice models. In: Paper presented at the proceedings of the 3rd Swiss transportation research conference. Ascona, Switzerland

Brouwer R, Bateman IJ (2005) Temporal stability and transferability of models of willingness to pay for flood control and wetland conservation. Water Resour Res 41:W03017

Campbell D, Hutchinson WG, Scarpa R (2008) Incorporating discontinuous preferences into the analysis of discrete choice experiments. Environ Resour Econ 41:401–417

Chilton S, Jones-Lee M, Kiraly F et al (2006) Dread risks. J Risk Uncertain 33:165–182

Corso PS, Hammitt JK, Graham JD (2001) Valuing mortality-risk reduction: using visual aids to improve the validity of contingent valuation. J Risk Uncertain 23:165–184

Davidson DJ, Freudenburg WR (1996) Gender and environmental concerns: a review and analysis of available research. Environ Behav 28:302–339

De Blaeij A, Florax RJGM, Rietveld P et al (2003) The value of statistical life in road safety: a meta-analysis. Accid Anal Prev 35:973–986

Eeckhoudt LR, Hammitt JK (2001) Background risks and the value of a statistical life. J Risk Uncertain 23:261–279

Ferrini S, Scarpa R (2007) Designs with a priori information for nonmarket valuation with choice experiments: A Monte Carlo study. J Environ Econ Manag 53:342–363

Green DP, Jacowitz KE, Kahneman D et al (1998) Referendum contingent valuation, anchoring, and willingness to pay for public goods. Resour Energ Econ 20:85–116

Hammitt JK (2000) Valuing mortality risk: theory and practice. Environ Sci Technol 34:1396–1400

Hammitt JK, Treich N (2007) Statistical vs. identified lives in benefit-cost analysis. J Risk Uncertain 35:45–66

Heberlein TA, Wilson MA, Bishop RC et al (2005) Rethinking the scope test as a criterion for validity in contingent valuation. J Environ Econ Manag 50:1–22

Itaoka K, Saito A, Krupnick A et al (2006) The effect of risk characteristics on the willingness to pay for mortality risk reductions from electric power generation. Environ Resour Econ 33:371–398

Johansson PO (2002) On the definition and age dependency of the value of a statistical life. J Risk Uncertain 25:251–263

Jones-Lee MW (1991) Altruism and the value of other people's safety. J Risk Uncertain 4:213–219

Kaplow L (2005) The value of a statistical life and the coefficient of relative risk aversion. J Risk Uncertain 31:23–34

Knetsch JL (2010) Values of gains and losses: reference states and choice of measure. Environ Resour Econ 46:179–188

Kochi I, Hubbell B, Kramer R (2006) An empirical Bayes approach to combining and comparing estimates of the value of a statistical life for environmental policy analysis. Environ Resour Econ 34:385–406

Leiter AM, Pruckner GJ (2009) Proportionality of willingness to pay to small changes in risk: the impact of attitudinal factors in scope tests. Environ Resour Econ 42:169–186

Louviere JJ, Hensher DA, Swait JD (2000) Stated choice methods: analysis and applications. Cambridge University Press, Cambridge

McFadden D (2001) Economic choices. Am Econ Rev 91:351–378

PLANAT (2005) Strategie Naturgefahren Schweiz. Technical report, published on behalf of the Swiss National Platform for Natural Hazards (PLANAT). http://www.planat.ch. Last accessed on:12/12/2009

Pratt JW, Zeckhauser RJ (1996) Willingness to pay and the distribution of risk and wealth. J Polit Econ 104:747–763

Revelt D, Train K (1998) Mixed logit with repeated choices: households' choices of appliance efficiency level. Rev Econ Stat 80:647–657

Schläpfer F (2008) Contingent valuation: a new perspective. Ecol Econ 64:729–740

Slovic P, Fischhoff B, Lichtenstein S (2000) Facts and fears: understanding perceived risk. In: Slovic P (ed) The perception of risk. Earthscan, London pp 137–154

Sunstein CR (2004) Valuing life: a plea for disaggregation. Duke Law J 54:385–445

Tengs TO, Adams ME, Pliskin JS et al (1995) 500 Lifesaving interventions and their cost-effectiveness. Risk Anal 15:369–390
Thiene M, Scarpa R (2009) Deriving and testing efficient estimates of WTP distributions in destination choice models. Environ Resour Econ 44:379–395
Train KE (2003) Discrete choice methods with simulation. Cambridge University Press, Cambridge
Viscusi WK, Aldy JE (2003) The value of a statistical life: a critical review of market estimates throughout the world. J Risk Uncertain 27:5–76
Viscusi WK, Magat WA, Forrest A (1988) Altruistic and private valuations of risk reduction. J Policy Anal Manag 7:227–245
Zhai GF, Ikeda S (2006) Flood risk acceptability and economic value of evacuation. Risk Anal 26:683–694